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Energy Benefits and Costs: Housing Insulation and the Use of Smaller Cars

by

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ABSTRACT

Two types of energy conservation programs are studied from the point of view that for a given monetary expenditure, energy costs as well as energy benefits will result. Specifically, we calculate the energy costs and benefits of a program to produce and install insulation in single-family houses and a program to replace the production of large cars by smaller cars. It is shown that both programs 'pay off' their energy costs promptly and yield an appreciable net benefit stream. Also, we compare the potential of these conservation programs to the current level of oil imports to appraise the importance of conservation in the drive for energy independence.

1. INTRODUCTION

Certain types of energy conservation offer the potentially desirable prospect of saving energy without significantly altering the quality of our lives. However, an initial investment may be required to change over to more energy efficient means of pursuing our goals. Two examples of this type of energy conservation are examined here with a view to quantifying the energy costs of the investment as well as the resulting energy benefits. Specifically, we consider a program to retrofit existing homes with ceiling insulation or with storm windows and doors and a program to replace the production of large cars with the production of more efficient smaller models. To quantify the energy costs of these projects we use the CAC energy input-output model to calculate the direct and indirect energy embodied in the material inputs to each program.[1] In each case, we assume that we have one million (1967) dollars to invest in conservation; then we calculate the resulting costs and benefits. From this point of view, we may think of these and other conservation options as being untapped reserves of energy which we may exploit if we are willing to make the initial investment. It should be emphasized that the dollar cost of these programs simply represents the cost of the newly-manufactured materials needed to switch to more efficient ways of doing things. (Energy costs are closely tied to this.) We have not attempted to appraise the cost to the government of supplying the incentive to make these changes.

The insulation program is studied on the basis of what may be accomplished by insulating a typical house. Sebald[2] has investigated

the potential heating savings for a hypothetical house, and using his results we calculate the total costs and savings obtainable from as many such houses as can be insulated for one million dollars. While some houses may be larger or smaller than our hypothetical house, we select this as an average and assume constant returns to scale. From this point of view the costs and benefits of an insulation program depends only on the amount we are willing to spend, and apply to all sizes of homes.

Our analysis of the benefits of changing from large cars to smaller cars is a calculation of the amount of gasoline that might be saved if the production of large cars were replaced by the production of smaller cars. We assume that whether a new car is large or small it will be driven the same mileage during its lifetime. The difference in fuel consumption accounts for the benefits calculated here. While the benefits of this program derive from the decision to begin producing small cars instead of continuing to turn out large cars, the cost of this decision may depend in part on the speed with which it is implemented. Possibly we could wait until a large car manufacturing facility reached obsolescence and then build a new facility for small cars in its place. In this way the incremental cost of the decision to change to smaller car output would be minimized. However, in this analysis we have made the most generous possible estimate of the cost of conversion. We have calculated an upper bound to the cost of converting a production facility to small car output by assuming that all existing capital equipment would have to be scrapped and replaced by new machinery more suitable for producing small cars. The procedure, then, is to estimate the extent of the

conversion that can be purchased for one million dollars and to calculate the incremental savings due to the smaller cars produced as a result of the conversion.

Section 2 of this paper is devoted to deriving the basic results on insulation and storms. Section 3 considers large car replacement. The final section of the paper summarizes the results of the preceding sections with a discussion of the feasibility of these programs and of the potential extent of their savings.

2. INSULATION AND STORM WINDOWS

2.1 Method

Preliminary to calculating energy savings due to retro-fitting houses with insulation or storms, we need to make some simplifying assumptions. Where possible, these assumptions will be conservative in nature so as to avoid overestimation of energy savings.

First of all, we assume that insulation and storms do not conserve energy used in air conditioning. Studies indicate that whatever savings are obtained by keeping heat out of a house during the day are negated at night by heat held inside the house by the insulation [3]. Thus our attention will be focused only on whatever energy can be saved in winter heating. Next, we will assume that no electricity used in heating can be saved by an insulating campaign. Only about 7% of all homes in the United States are heated electrically and most of these are in the south, where less heating needs to be done. Furthermore, due to the relatively high price of electricity, almost all homes that are heated electrically are also well insulated. Thus we will assume that all the energy savings of an insulation program are in either gas or oil; in fact, one can think of the results that follow as applying only to uninsulated homes heated by gas or oil.

The amount of energy saved and the split between oil and gas savings depend on climatic conditions and the fraction of homes heated by each fuel. Let R_1, R_2 and R_3 denote the northern, central and southern regions of the country, respectively. For our purposes, these regions were defined as consisting of those states where the average heating degree day (HDD) totals fall into three mutually exclusive intervals:

R_1 (Northern) - HDD $\geq$ 6000

R_2 (Central) - 6000 $\geq$ HDD $\geq$ 4000

R_3 (Southern) - 4000 $\geq$ HDD

Also let R_o be the region consisting of the whole United States. Given the average HDD figures for key cities in each state [4] and the number of homes heat by oil and by gas [5] it is straightforward to compute for each region R_i $i = 0, 1, 2, 3$ an average heating degree day total H_i, weighted by the total oil or gas heated homes of each state in the region. Let H_k represent the average heating degree day total for state k and let a_k and b_k represent the total homes in state k heated by oil and by gas.

gas.

Then $H_i = \dfrac{\sum_k H_k (a_k + b_k)}{\sum_k (a_k + b_k)}$

where the summations are over all states k in region i. The values obtained in this way are:

$$H_0 = 4761$$
$$H_1 = 7170$$
$$H_2 = 5421$$
$$H_3 = 2575$$

Also, we compute a fraction f_i of oil heated homes in each region

$$f_i = \frac{\sum_k a_k}{\sum_k (a_k + b_k)}$$

$$f_0 = .277$$
$$f_1 = .415$$
$$f_2 = .307$$
$$f_3 = .160$$

Using this information on climate and heating mode in the four regions we are able to calculate the energy savings of three conservation options:

1. 6" of ceiling insulation in an uninsulated home
2. Installation of storm windows and doors
3. Storms and 6" insulation in an uninsulated home

For a typical house, Sebald [2] has calculated heating savings per heating degree day. Assuming an efficiency of 75% [6] in converting a Btu of either gas or oil to space heat, the conservation options named above have the following fuel savings per heating degree day, S_i, per house:

$$S_1 = .104 * 10^5 \text{ Btu}$$

$$S_2 = .0613 * 10^5 \text{ Btu}$$

$$S_3 = .1653 * 10^5 \text{ Btu}$$

Each of these options has a dollar cost (expressed in 1967 dollars) per house, K_i:

	Materials	Installation , Overhead, Profit	Total
K_1	\$ 84	\$ 94	\$178
K_2	\$451	\$367	\$818
K_3	\$535	\$461	\$996

These figures were obtained by applying construction cost estimates [7] to the house described in Table 1. Specifically, the cost of 6" of insulation was estimated at .08 $\$/ft^2$ for material, .04 $\$/ft^2$ for installation and .05 $\$/ft^2$ for overhead, profit and contingencies. The ceiling area requiring insulation was assumed to be 1044 ft^2. To obtain cost estimates for storm windows and doors we assume two doors

at \$50 each for materials, \$13 each for installation plus the recommended 40% to cover overhead, profit and contingencies. Two sizes of windows are listed in [7]; costs per square foot were estimated for each size and an average was obtained by using weights of 1/3 and 2/3 for the larger and smaller sizes respectively. Given this average cost per

TABLE 1

The Model Home

Floor Area:	1200 ft^2 (Assume 30 ft x 40 ft. Assuming rafters on 16 in. centers and a 3% safety factor, area between rafters is estimated at 1044 $ft.^2$)
Windows:	Double hung wood North 60 ft^2 South 75 ft^2 East 25 ft^2 West 35 ft^2
Exterior Walls:	1/2 in x 8 in. lapped wood siding 25/32 in. insulated board sheathing 3 5/8 in. air space 1/2 in. gypsum wall board
Ceiling:	3/8 in. gypsum board
Roof:	Asphalt shingles Building paper 25/32 in. wood sheathing
Attic:	Natural ventilation (0.1 cfm/ft^2)
Floor:	3/4 in. hardward floor Felt 25/32 in. wood subfloor

Source: See reference [2]

square foot of window the total cost was obtained by multiplying this average by the total window area (assumed to be 195 ft^2).

The yearly energy savings in Btu's obtained from an expenditure of one million dollars on option j in region i can now be calculated as:

$$O_{ji} = \frac{S_j * 10^6}{K_j} * f_i * H_i \text{ for oil, and}$$

$$G_{ji} = \frac{S_j * 10^6}{K_j} * (1-f_i) * H_i \text{ for gas.}$$

Also, we may summarize the savings of oil and gas in terms of primary energy. Since it takes energy to extract, refine and deliver oil and gas to the home, we account for this by multiplying oil and gas savings by their energy intensities ε_o and ε_g, which were obtained from the CAC energy input-output model [1]. The energy intensities represent the total (primary resource) energy required per Btu of oil or gas delivered to the home:

$$\varepsilon_o = 1.2082$$

$$\varepsilon_g = 1.1005$$

The total primary energy saved by option j in region i is then equal to $\varepsilon_o * O_{ji} + \varepsilon_g * G_{ji}$. The results of these calculations are shown in Table 2 along with the energy costs of these programs which we calculate below.

The energy input cost of a million dollars spent on conservation option j is the same regardless of the region in which it is instituted. Before we can calculate the direct and indirect energy inputs of an option, we need a breakdown of its cost:

OPTION	INSULATION	STORM WINDOWS AND DOORS	INSTALLATION
1	47%		53%
2		55%	45%
3	8.5%	45.5%	46%

These percentages are obtained from the same considerations as those from which the cost estimates were derived earlier. The energy inputs of an option are obtained by summing the inputs to each of its components; insulation, storms, and installation. Thus the direct and indirect energy inputs involved in an expenditure of one million dollars on option 2 represent the energy embodied in $555,000 worth of storms and $450,000 worth of installation.

The energy intensity of installation is estimated (arbitrarily) to be roughly the same as that of Retail Trade [1]:

COAL	CRUDE	REFINED OIL	ELECTRICITY	GAS	PRIMARY ENERGY
.0741	.258	.121	.0358	.130	.354

(all figures in 10^5 Btu's per 1967 dollar)

Since the costs of insulation and storms have been given here in prices to the contractor, it is necessary to convert the energy intensities of insulation (I-O sector 36.20) and storms (I-O sector 40.05)

from producers prices to contractors prices by taking account of transportation and trade margins on domestic transactions. Let ε_i represent the energy intensity of a given sector and let $\varepsilon_1\ \varepsilon_2 \ldots \varepsilon_8$ be the energy intensities of the eight transportation and trade sectors. Then we may convert the intensity ε_i in producers price to a contractors price intensity, e_i, by the formula:

$$e_i = \frac{\varepsilon_i * DA_{ij} + \sum_{k=1}^{8} \varepsilon_k * MDT_{m_k j}}{DA_{ij} + \sum_{k=1}^{8} MDT_{m_k j}}$$

In this formula, sector j is I-O sector 11.01, the new residential construction sector, and $m_1 \ldots m_8$ are the transportation and trade sectors. The matrices DA and MDT represent U. S. Department of Commerce Bureau of Economic Analysis (BEA) data for 1967 on direct allocations and margins on domestic transactions [8].

Applying this formula to the energy intensities of insulation and storms yields the following intensities in contractors prices.

	COAL	CRUDE	REFINED	ELECTRICITY	GAS	PRIMARY
Insulation (36.20*)	.317	.905	.211	.0830	.660	1.27
Storms (40.05*)	.374	.551	.152	.133	.384	1.008

(All figures are in 10^5 Btu's per 1967 dollars;
*represents BEA Sector number)

2.2 Results

Now we can calculate the energy cost of one million dollars spent on option j. We simply multiply the energy intensity of each input to option j by the total dollar cost of that input and sum these products. The results of this calculation for each of the three options are shown below along with the benefits.

TABLE 2

ENERGY COSTS AND BENEFITS
OF ONE MILLION DOLLARS SPENT ON INSULATION AND STORMS
(UNITS: 10^{11} Btu)

ANNUAL ENERGY BENEFITS

	OIL	GAS	PRIMARY ENERGY
BENEFITS (Region = Whole U.S.):			
Insulation	.770	2.011	3.14
Storms	.098	.258	.402
Insulation and Storms	.219	.571	.893
BENEFITS (Region = Northern U.S.)			
Insulation	1.74	2.45	4.80
Storms	.223	.314	.615
Insulation and Storms	.493	.696	1.36
BENEFITS (Region = Central U.S.)			
Insulation	.972	2.19	3.85
Storms	.125	.281	.460
Insulation and Storms	.276	.623	1.02
BENEFITS (Region = Southern U.S.)			
Insulation	.241	1.26	1.68
Storms	.031	.162	.216
Insulation and Storms	.068	.359	.477

ENERGY COSTS

	COAL	CRUDE	REFINED OIL	ELECTRICITY	GAS	PRIMARY ENERGY
Insulation	.188	.562	.163	.058	.379	.784
Storms	.239	.419	.138	.270	.270	.713
Storms & Insulation	.231	.446	.143	.291	.291	.729

3. CONVERSION TO SMALLER CARS

3.1 Method

Changing over from the manufacture of big cars to smaller sizes has obvious benefits in gasoline conservation but also energy costs in retooling to accommodate the differences in production. To obtain a liberal estimate of these costs, let us suppose that such a conversion requires a complete turnover (by the auto maker) of capital equipment produced by the following I-O sectors:

	SECTOR	Capital Coefficient
40	Heating, Plumbing & Fabricated Struc. Metal Products	.0023
42	Other Fabricated Metal Prod.	.0034
43	Engines & Turbines	.0008
46	Materials Handling Mach. & Equip.	.0179
47	Metalworking Machinery & Equip.	.0539
48	Special Industry Machinery & Equip.	.0014
49	General Industrial Machinery & Equip.	.0113
53	Electric Transmission & Distribution Equip. & Electrical Industrial Apparatus	.0088
65.1	Railroad Transportation	.0007
65.3	Motor Freight and Warehousing	.0016
65.4	Water Transportation	0.0
65.5	Air Transportation	0.0
65.7	Transportation Services	.0002

The capital coefficients in the second column represent the value of each type of capital equipment required during a year to support the production

of a dollar of output from I-O sector 59 (Motor Vehicles and Equipment).*
The coefficients of the five transportation sectors represent the transportation margins associated with getting the capital equipment into place. They come from the same source as the other coefficients but have been altered here to reflect the limited transportation costs associated with the capital sectors listed above rather than all capital contributing sectors. Since the sectors listed here contribute 35% of the total capital requirements, the coefficients for the transportation sectors have been scaled down proportionately.

Now we can evaluate the energy cost of turning over one million dollars of capital in the auto industry. Since the sum of the coefficients is .102, such a turnover allows the conversion of enough facilities to produce $10^6/.102 = \$9.8*10^6$ worth of output per year. If we multiply each of the capital coefficients by that amount, the result is what we must spend on capital equipment from each of those sectors. Multiplying these expenditures by the energy intensity of the corresponding I-O sectors [1] and adding the results, the total is the direct and indirect energy cost of the one million dollar expenditure. Thus, if ε_{ik} is the direct and indirect energy of type i embodied in one dollar of capital of type k and C_k is the capital coefficient for capital of type k, then $\sum_k \varepsilon_{ik}*C_k*9.8*10^6$ is the direct and indirect

* The data for these capital coefficients come from Battelle [9], but we have made them compatible with our own I-O system by inflation to 67 dollars, and aggregation [10].

cost in type i energy of our one million dollar capital turnover. The energy costs obtained in this way are shown in Table 3b along with the benefits calculated below.

The benefits derived from such a turnover may be evaluated by estimating the number of cars that might be replaced by smaller cars because of this conversion and by estimating the amount of gasoline saved by each car. The average (producers') price of a car in 1967 was $2,100 [11]. Spending one million dollars on new production equipment allows the output of 9.8 million dollars worth of cars in smaller sizes. Therefore, some $9.8*10^6/2,100 = 4666$ cars could be scaled down in size as a result of our spending, and this is in only the first year. Thereafter, of course, no other extra expenditures would be required to keep the size of the automobile output scaled down. Thus in the first year we benefit from the gasoline savings of 4666 smaller cars, in the second year from 9332 cars and so on.

Note we are assuming that cars cost the same, regardless of size. We ignore this effect and assume that cars are replaced one for one.

If we change from large cars to compact cars, we can hope for a gain in mileage from perhaps 12 m.p.g. to 20 m.p.g. or a savings of $1/12 - 1/20 = .0333$ gallons per mile. A change from large to subcompact might save $1/12 - 1/28 = .0476$ gallons per mile in each car. A gallon of gasoline is 125,000 Btu so these savings are 4160 Btu's per mile and 5950 Btu per mile respectively.

The U. S. Department of Transportation [12] has estimated the mileage of a car by age. Table 3a reproduces those figures as well as the total Btu's saved by the fleet of 4666 cars produced in the

first year after the one million dollar capital turnover. For example, in the first year, 4666 mid-size cars each saving 4160 Btu of gasoline per mile and driving 14500 miles save a total of 4666 * 4160 * 14,500 = 2.82 * 10^{11} Btu.

TABLE 3a

(Mileage of cars by age and resulting gasoline savings of first year's output of 4666 cars)

Year	Mileage per car	Option 1 - Btu Savings (Large to Compact -) (Units are 10^{11} Btu's)	Option 2 - Btu Savings (Large to Subcompact) (Units are 10^{11} Btu's)
1	14,500	2.82	4.03
2	13,500	2.62	3.75
3	11,500	2.23	3.19
4	10,000	1.94	2.78
5	9,900	1.92	2.75
6	9,900	1.92	2.75
7	9,500	1.84	2.64
8	8,500	1.65	2.36
9	7,500	1.46	2.08
10	5,700	1.10	1.58

While Table 3a lists the yearly savings of the initial year's output of cars, Table 3b shows the Btu savings in both gasoline and the equivalent in primary energy contributed by the cars produced in years 1, 2 ...... For example, in year three after the capital turnover, the savings of three years output of cars are realized. These

savings result from a new fleet of 4666 cars driving an average of 14,500 miles each, 4666 cars made a year earlier driving 13,000 miles each and the initial group of 4666 cars, each driving 11,500 miles in their third year of use. Thus, the act of retooling saves progressively more gasoline in each succeeding year until a steady state is reached after 10 years when the first batch of the smaller cars is finally retired from service.

Energy costs are also summarized in Table 3b. Clearly they are far exceeded by the benefits, and the investment appears to be slightly more energy-effective than the insulation programs discussed earlier.

TABLE 3b

TOTAL YEARLY ENERGY SAVINGS DUE TO ONE MILLION DOLLAR CAPITAL TURNOVER

YEAR	OPTION 1: Btu Savings of Gasoline (Large to intermediate-units are 10^{11} Btu)	Btu Savings in Primary Energy
1	2.82	3.40
2	5.44	6.57
3	7.67	9.26
4	9.61	11.61
5	11.53	13.93
6	13.45	16.25
7	15.30	18.48
8	16.95	20.47
9	18.40	22.23
10	19.51	23.57

YEAR	OPTION 2: Btu Savings of Gasoline (Large to Compact - units are 10^{11} Btu)	Btu Savings in Primary Energy
1	4.03	4.86
2	7.77	9.39
3	10.97	13.25
4	13.74	16.60
5	16.49	19.92
6	19.24	23.25
7	21.88	26.43
8	24.24	29.28
9	26.32	31.80
10	27.90	33.71

ENERGY COSTS

COAL	CRUDE	REFINED PETROLEUM	ELECTRICITY	GAS	PRIMARY ENERGY
.253	.307	.105	1489	.194	.591

(all figures in 10^{11} Btu's)

4. RESULTS

4.1 Feasibility

We may calculate payback periods in terms of primary energy to underscore the worth of both types of conservation programs. For the three insulation options applied to the whole U. S. (i.e. 6" ceiling insulation, storm windows and doors and both storms and 6" insulation) the payback periods are .25, 1.77 and .82 years respectively. For the conservation program consisting of scaling down car size, the payback times are .17 and .12 years for large to compact and large to sub-compact respectively. Of course, in the case of large car conversion, the incremental savings continue to increase each year after the original capital turnover. Thus, the above payback times, although excellent, really understate the value of such an undertaking.

Now consider the dollar cost of obtaining energy through either type of conservation. In both instances, we pay an initial fee and receive a stream of energy in future years. For the sake of comparison, consider that the cost of imported oil is now more than ten dollars per barrel. At this rate one million dollars will purchase $6.13*10^{11}$ Btu's worth of primary energy. It would be somewhat inappropriate to attempt a completely analytical comparison of importing oil versus conservation within the context of this paper. For one thing, the price of imported oil above is given in 1975 dollars rather than 1967 dollars as are the prices on the conservation programs. Furthermore, the problem of just how best to discount an energy stream is a sticky one. However, even without attempting to resolve these issues some of the conservation options stand out as being clearly better buys than imported oil. In particular, the ceiling insulation

and large car conversion would certainly surpass importing oil in value even if the 1975 cost of those conservation programs were twice the 1967 cost. Some of the programs to install storm windows and doors do not appear particularly favorable in comparison to imported oil, even though they represent an eventual net energy gain. But it is good to remember that many other considerations may affect the relative values of these sources of energy. For example, money spent on storm windows also buys American jobs and the investment entails very little risk. On the other hand, there is a good deal of uncertainty in the future price of imported oil, and the possibility of another sudden cutoff represents a hidden cost which should not be ignored though it might be unquantified.

4.2 Savings Potential of Car Conversion

Having made conservative assumptions about the feasibility of saving energy through some of the conservation steps analyzed here, we turn next to a discussion of their potential for savings. To obtain a rough idea of the importance of large car conversion, we proceed by assuming a given level of domestic output of large cars. The total potential for savings, then, is the gasoline saved by reducing this output to zero. Of course, the market for automobiles of all sizes is in a state of considerable flux; in particular, the demand for the larger sizes of cars has declined drastically. In this respect, the program to save energy by phasing out large cars may be said to have begun already, spontaneously, and without any external inducement to turn over capital equipment as discussed earlier. While it is possible that sales of large cars may recover significantly, the estimate used here

is based on 1974 data to avoid overstating the potential for energy savings.

The analysis of large car conversion was framed here in terms of replacing the new production of large cars by compacts or subcompacts. For our purposes, these three categories were assumed to achieve mileage levels of 12, 20 and 28 mpg respectively. The categories most often used to classify cars by size are standard, intermediate and small. The last of these categories, small cars, essentially contains as a subset those automobiles that can achieve at least 20 mpg. On the other hand, the standard and intermediate classes generally do not attain this much fuel economy. Most standard size cars are in the 12 mpg range along with a great many intermediates. However, to stay on the conservative side let us suppose that our 12 mpg category is only as large as the standard size category. In 1974, this amounted to 2 million cars [13].

The savings in Table 3b result from replacing a yearly output of 4666 large cars by the same output of smaller cars. Therefore, the savings obtained by eliminating the production of 2 million large cars per year and replacing them by smaller cars can be calculated by multiplying the figures in Table 3b by $2*10^6/4666 = 430$. The resulting figures range in order of magnitude from 10^{14} BTU of primary energy during the first year up to 10^{15} Btu in the tenth year as the last big cars (made before the change over) are retired from service. Note that this is based on the unrealistic and probably undesirable premise that production facilities with a yearly capacity for 2 million large cars would be shut down immediately and their output replaced by

2 million new small cars each year. In any realistic scenario, a switch would take place gradually; but in that case the savings would be slower to accrue. The figures given above simply represent the maximum potential for savings and this depends on immediately eliminating the yearly output of 2 million new large cars and putting out smaller cars in their place.

4.3 Savings Potential of Insulation

The potential savings due to insulating houses may be obtained given the number of uninsulated houses in the country. Current estimates indicate that there are 18 million under-insulated houses; these houses have less than three inches of ceiling insulation and 43% have no ceiling insulation at all [14]. During the 1950's when many of these houses were built, energy was so cheap that even the insulated houses were only minimally insulated. A common approach to ceiling insulation was the use of 2-1/2 inches of vermiculite. At its best, vermiculite is still twice as heat conductive as fiberglass [15]. Over a long period of time, vermiculite and many other insulating materials will tend to compact and lose both overall thickness and insulating quality per inch in the process. It is not known what additional savings may be obtained by replacing or supplementing old ineffective insulation by 6 inches of modern insulation. However, to avoid drastically under-stating the case for conservation through insulation, the under-insulated homes ought to be included somehow in an estimate of potential savings. Suppose that installing 6 inches of insulation in these already poorly insulated homes will result in the same energy costs but yield only half the energy savings.

The costs and benefits due to an expenditure of one million dollars are listed in Table 2. Since the dollar cost per house was estimated to be $178, the figures represent the savings and costs due to $10^6/178 = 5600$ houses. Therefore, the cost of retro-fitting all 18 million houses are the costs in Table 2 multiplied by $18*10^6/5600 = 3200$. On the benefits side, the savings in Table 2 apply only to the uninsulated houses while the remaining houses contribute energy savings at only half the uninsulated rate. For the whole U. S. the savings due to insulation are given as $3.14*10^{11}$ Btu per year for $10^6/178 = 5600$ houses or $3.14*10^{11}/5600 = 5.6*10^7$ Btu per year for each house. Therefore, the total yearly savings are estimated at

$$.43*(18*10^6)*(5.6*10^7) + .57*(18*10^6)* \frac{5.6*10^7}{2} = 7.2*10^{14} \text{ Btu per}$$

year in primary energy.

4.4 Comparison with Energy Imports

To appraise the importance of these conservation programs in the drive to achieve energy independence, we may compare the size of their benefits with the amount of oil that we import. For example, in 1974 this country imported $7.11*10^{15}$ Btu's of crude oil and $5.78*10^{15}$ Btu's of refined petroleum. In terms of primary energy, this amounts to $14.5*10^{15}$ Btu's.** We calculated that completely removing large cars

** The primary energy equivalent of refined or crude oil includes that needed to pump, transport and process oil.

from use would yield yearly savings on the order of 10^{15} Btu's of primary energy. Insulating only those houses most sorely in need of more insulation could save nearly 10^{15} Btu's each year. Thus, these two programs alone would take a significant bite out of our national energy deficit. Furthermore, these programs are but two of many similar measures. For example, Pilati [16] has shown that a program to set back thermostats to 55° at night and 68° during the day could save $3*10^{15}$ Btu's in the residential sector alone. In addition, engineering better mileage into all sizes of cars and making better use of rail transit both might be expected to make important contributions to the energy situation. Also, it should be noted that even a modest reduction in oil imports goes a long way toward undermining the political leverage of an oil embargo; currently about one-third of our imports come from the mideast. The conservation measures discussed here do require a considerable energy investment, but their high net yield makes this initial investment quite worthwhile.

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